MOORED CURRENT MEASUREMENTS OVER THE CONTINENTAL SLOPE OF THE OCEAN'S EASTERN BOUNDARY.

&

AN INVESTIGATION OF THE POLEWARD UNDERCURRENT OVER THE CONTINENTAL MARGIN OF NORTH AMERICA.

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LONG-TERM GOALS

Our goal is to determine the velocity and property fields along the ocean's eastern boundaries and to understand the dynamics controlling them.

OBJECTIVES

Our objective is to measure the average and time-varying mesoscale structure in the currents over the continental slope, the region where meandering coastal upwelling jets, the subsurface undercurrent, and eddies interact and influence the flow which makes up the eastern boundary current.

APPROACH

To examine the time-varying structure of the currents over the continental margin time-series of velocity and temperature were made from a coherent array of 5 moorings in a X pattern near 38.5 N during the two year Eastern Boundary Current ARI field experiment (June 1992- June 1994). To explore the large-scale structure of the same current field, ADCP data were acquired in July-August 1995 during the triennial NOAA NMFS acoustic and trawl survey of Pacific whiting, which extended from 34 N to 54 N. Figure 1 indicates the geographical extent of the ADCP survey of July-August 1995, the positions of the 1992-4 EBC five-element X slope array moorings deployed in a cooperative effort with Dr S. Ramp, and two moorings of the adjacent EBC array deployed offshore by Drs Chereskin and Niiler (SIO). Although not coincident in time, the ADCP survey and the mooring arrays are complementary, with the former providing information on the spatial extent and variability of the flow and the latter giving the temporal mean and variability.

WORK COMPLETED

The five EBC slope array moorings were initially deployed in June 1992, recovered and redeployed in May 1993 and recovered in June 1994. The processed data from the EBC slope array are described in an on-line electronic data report available at http://kepler.oce.orst.edu/bg.html. In order to join time-series from the two deployments, and to

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provide time-series of velocity and temperature at fixed depths, the original series were interpolated to provide time-series at the constant pressure levels of 100, 125, 150, 175, 275, 325, and 575 db where possible. During the second deployment period (May 1993 - June 1994), ADCP instruments were moored and data from them were used to provide velocity time-series at 25, 50, and 75 m depth. The ADCP data from the NOAA/NMFS survey will be made available in a joint technical report with NOAA NMFS; a selection of that data can be seen now at http://streak.oce.orst.edu/puc_sections.html. Results have been presented at national and international meetings and manuscripts presenting the results are in preparation.

RESULTS

Equatorward surface jets and subsurface poleward undercurrents are ubiquitous features of eastern boundary current regions (Huyer *et al*., 1996; Smith *et al*., 1997a). Recently, we have focused on the poleward undercurrent, whose alongshore continuity has been a matter of much speculation but few observations.

In July - August 1995, ADCP transects were made across the continental margin from 34 N to 51 N at about 20 km N-S spacing, yielding 110 velocity sections (Wilson et al., 1996). In 86 of the 110 transects, a poleward undercurrent with speed > 5 cm/s, width > 10 km and thickness > 100 m at 200 m was evident (Figure 1) (Pierce *et al*., 1996; Kosro *et al*., 1996b). The core (centroid) of the poleward flow has been determined at each of the NOAA/NMFS velocity sections; the depth of the core decreases with increasing latitude and is significant at the 95% level. Assuming the depth of the core flow is a reasonable estimate for the thickness of the flow H, we find the potential vorticity f/H remains nearly constant (where f is the Coriolis parameter); the dashed line is the f/H constant. If the poleward flow is continuous, f/H following the flow must remain constant under simple quasi-geostrophic inviscid dynamics, a good assumption for the deep, slow poleward flow. The maximum velocity of poleward flow at each section also has 95% significant slope with latitude. This is consistent with a thickening and weakening, but continuous, undercurrent which maintains its transport.

The spatial survey data from 1995 is consistent with the velocity time-series from the mooring array near 38.5 N during 1992-4. The moored array showed a poleward undercurrent, strongest near the shelf break, constrained to flow along topography over the upper slope but much less polarized over the mid and outer slope (Figure 2) (Kosro *et al*., 1996b, 1997a). The along-slope component (toward 330 degrees) of the mean velocity at 175 m decreases from 11 cm/s at ME, 5.3 at MC, 2.6 at MW, 1.5 at IC, to 1.1 cm/s at IW; the e-folding decay scale is approximately 24 km across the 5 element cross-margin array spanning 56 km. The most energetic Empirical Orthogonal Function computed for the slope array shows 48% of total variance is strongly polarized along isobaths, coherent across the slope, and dominated by very low frequency variability (strongly peaked at 60 days period); the 60 day peak in spectra seems trapped to the continental margin and associated with the poleward undercurrent. Fluctuations of this mode are coherent with fluctations in coastal sea level, establishing a connection between the slope and the coastal flows. The next two EOFs are a cross-shore mode, which decays with depth and with shallower water, but which has some surprisingly long-lived events (with currents crossing topography for many days in a row), and an eddy mode, with strong cyclonic and anticyclonic eddies contributing to the variance.

IMPACTS/APPLICATIONS

The strong poleward flow at relatively shallow depths (100 to 300 m) over the inner continental slope off the west coast of the USA is persistent spatially and temporally, even in the region of mean equatorward winds and near-surface currents. Poleward undercurrents seem capable of transporting bio-geo-chemical material over appreciable distances, counter to the prevailing winds and surface currents.

RELATED PROJECTS

The results of this program have a direct impact on the other projects with the Eastern Boundary Current ARI and will help explain the distribution and variability observed in the other physical, chemical and biological fields. The results should be of interest to those concerned with subsurface operations near the continental margins and to those concerned with fisheries. Poleward undercurrents, such as observed along the continental margin adjacent to the California Current, are common features of eastern boundary currents; a successful model of the flow regime along the eastern boundary of the ocean must take their presence into account.

In related work, P. M. Kosro, J. A. Barth and P. T. Strub have used joint funding from ONR (DURIP) and NSF (ARI) to obtain and evaluate a coastal surface current radar system, to be used in studies of the coastal jet, flow interaction with topography, and shelf/slope exchange. These systems use Bragg backscatter of radio waves to estimate the surface current, producing a sequence of hourly maps, with horizontal resolution of 1 to 3 km and range of order 40km. After conducting field trials of commercially-available systems (Kosro *et al*., 1996a), one of which provided a high-resolution glimpse at the spring transition to upwelling and the genesis of the coastal upwelling jet (Kosro et al., 1997a), a three-site SeaSonde system was selected for purchase; this system uses direction finding techniques with a compact crossed-loop/monopole receiving antenna. Field testing began in October 1996, and the radars were installed at long-term sites in May 1997. Over the spring and summer we have worked with the manufacturer to optomize each site and to characterize the conditions that affect the range and angular distribution of radar returns. In October 1997, we established a third site at Yaquina Head, Oregon. An acoustic current profiler was deployed in 80m of water in the radar coverage region on 9 August 1997. This instrument was recovered on 14 October and redeployed on 21 October 1997, from the 37’ research vessel Sacajawea.

REFERENCES

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http://kepler.oce.orst.edu/bg.html http://streak.oce.orst.edu/puc_sections.html

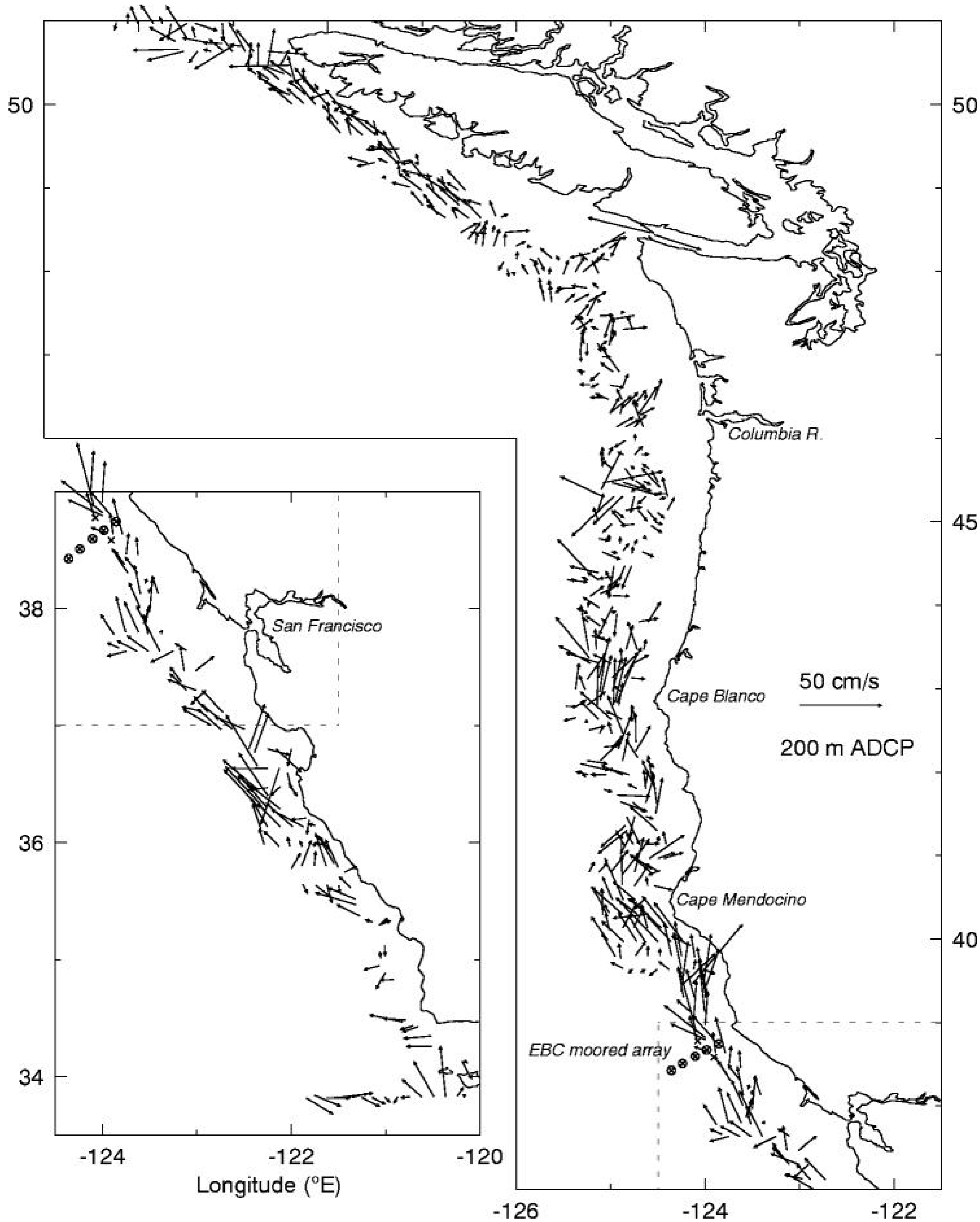

Figure 1. Directly-measured currents at 200m from a shipborne ADCP on the *R/V Miller Freeman*, July-August 1995 (Pierce *et al.*, 1996).

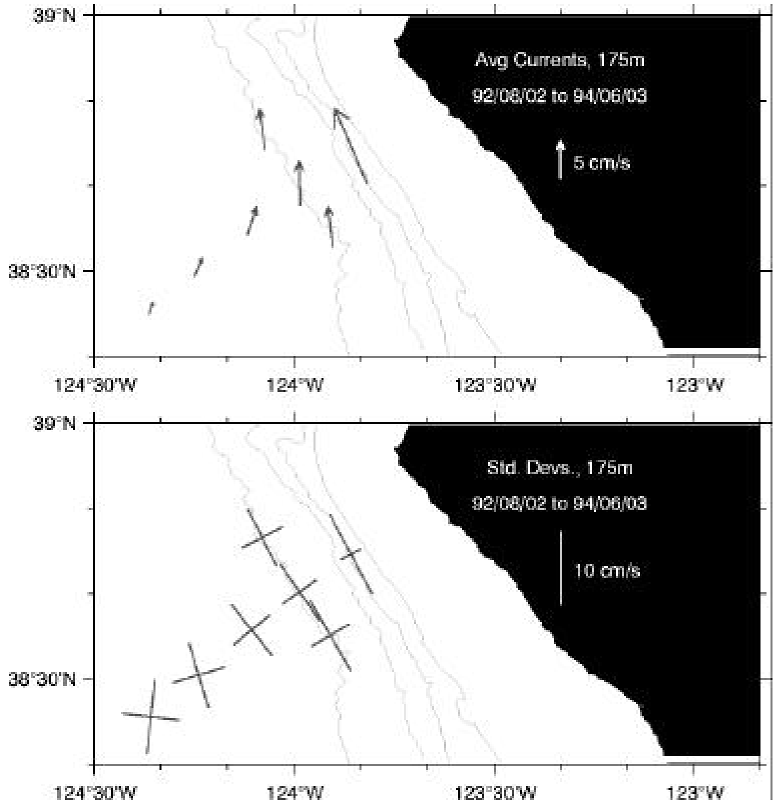

Figure 2. Mean currents at 175m depth, and fluctuations about the mean, for moorings located across the continental slope. The poleward undercurrent is strongest near the shelf break, and most strongly follows topography where bottom depth is smallest.

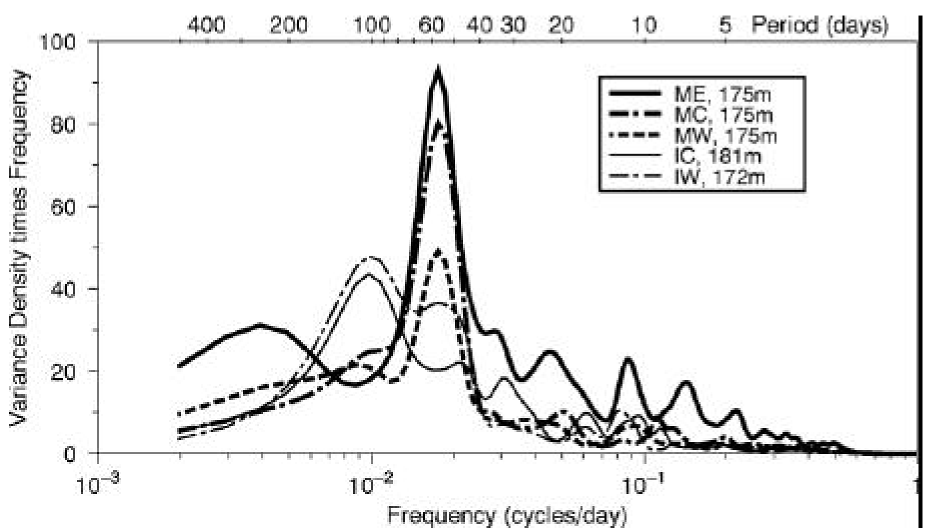

Figure 3. Spectrum of along-isobath current at 175m for each mooring along the central line, in variance-preserving form. A pronounced peak of fluctuations at 60-day periods is evident, decreasing in strength with increasingly offshore location.

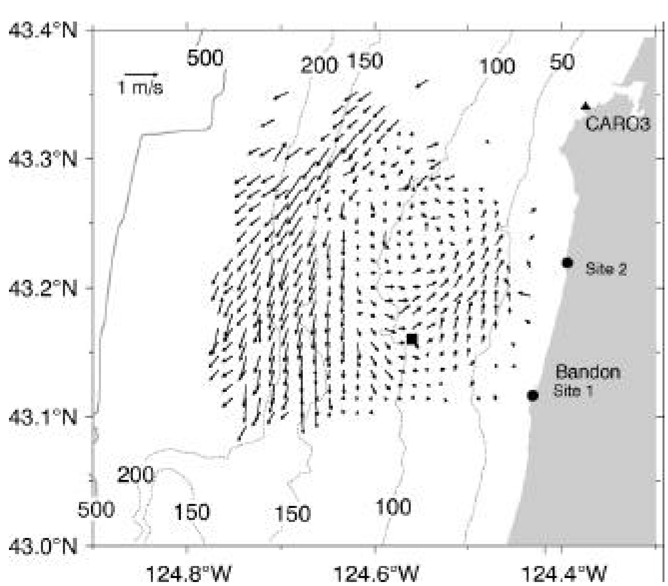

Figure 4. Example of surface current data collected hourly along the Oregon coast during a recent test of HF radar (Kosro, *et al*., 1996a, 1997a). Using funds from ONR, NSF and OSU, we have purchased and installed a SeaSonde HF system, to allow time-series mapping of current structure, response to wind forcing and topography.